DOCUMENT RESUME

ED 199 062 SE 034 287

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TITLE Astronomy Activities for the Classroom.
INSTITUTION South Carolina State Dept. of Education, Columbia.
PUB DATE [80]
NOTE 35p.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Astronomy; *Demonstrations (Educational); Earth Science; *Instructional Materials; Physical Sciences; *Science Activities; Science Curriculum; Science Education; *Science Instruction; Secondary Education; *Secondary School Science; Space Sciences

ABSTRACT

Presented are middle school level, activity-oriented astronomy activities developed as a result of an earth science workshop for teachers. Topics include: (1) sun and moon position and measurement; (2) daily, yearly, and seasonal changes in the sun's position; (3) shapes and positions of planetary orbits; (4) eclipses; (5) properties of light; (6) atmospheric pressure; and (7) characteristics of pinholes, lenses and mirrors. (DS)

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ASTRONOMY ACTIVITIES FOR THE CLASSROOM

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ACKNOWLEDGMENTS

These activities were developed as a result of an earth science workshop that was held at Wofford College. Many people have been instrumental in providing the opportunity, encouragement, and assistance essential for the development of this booklet:

Dr. Beverly Enwall, Chief Supervisor of the Curriculum Development Section

Dr. B. G. Stevens, Dean of Academic Affairs, Wofford College

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PREFACE

The development of science education has undergone considerable change in the last two decades. From the days when students were required to memorize long lists of terms, we have progressed to today's activity-oriented classes. But still many teachers need more resources to provide their students with a sufficient number of activities to make the classroom "come alive" with interest.

For a course to be taught properly, the fundamental principles must be reinforced with easy-to-do hands-on experiences for all the students. Quick and easy activities must be designed so that the lesson will be effective without becoming overwhelming and time consuming. Materials must be inexpensive and readily available. With this in mind, *Astronomy Activities for the Classroom* has been developed.

These activities, originally tested by teachers during a workshop for earth science teachers held at Wofford College, have now been printed for statewide distribution to all South Carolina earth science teachers. These activities are printed so they can be easily reproduced on a photocopier if necessary.

It is hoped by the authors that these activities will stimulate an interest in and appreciation for Astronomy that will grow as the students mature.

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Title: Moon Phases: Simulation

Materials: A black ball at least five centimeters (two inches) in diameter, a jar that will hold the ball, and a flashlight

Procedure: This activity will illustrate that the phases of the moon are caused by the changing positions of the sun and moon. Starting this activity about the time of a full moon will ensure a better understanding of these phases.

1. Check a calendar for the dates of the following phases of the moon: full moon, third quarter, new moon, and first quarter. Write the dates on cards for use later in the activity.

2. Place a ball, which will serve as the moon, on the top of a jar and set the jar in the middle of a table. Position the table so that it can be walked around. (Note: A black ball works best for this activity; however, if one is not available, a tennis or golf ball painted black may be used.)

3. Position a flashlight on the table so that it shines directly on the moon.

4. Turn on the flashlight and darken the room.

5. Walk around the table in a counterclockwise direction, so that each phase of the moon can be observed. By doing this, it should be understood why the shape of the moon seems to change during the course of a month. (Note: Half of the moon is lighted at all times.)

6. Decide where the cards with the dates of the phases belong. Place each card in its proper place.

FULL MOON

7. Walk around the table sketching each phase as it is seen by earthlings. Start at the position where all the lighted sides of the moon are visible (full moon).
HOW IT LOOKS TO EARTHLINGS

WANING GIBBOUS MOON

8. Move on to the next position, one eighth of a turn, and sketch that. This lopsided moon is called a waning gibbous moon.
HOW IT LOOKS TO EARTHLINGS

THIRD QUARTER MOON

9. The next position stop is one fourth the way around the table. This is a simulation of the moon during the third quarter. Notice that only a forth (quarter) of the moon is seen lighted by earthlings. Sketch this.
HOW IT LOOKS TO EARTHLINGS

WANING CRESCENT

10. Now the crescent becomes smaller or wanes. Sketch the waning crescent.
HOW IT LOOKS TO EARTHLINGS

NEW MOON

11. During the new moon phase, the moon cannot be seen by earthlings. What has happened to it? Sketch this.
HOW IT LOOKS TO EARTHLINGS

WAXING CRESCENT

12. As the rotation around the table continues, the moon will begin to grow or wax. This is the waxing crescent. Sketch this phase. (Note: Amateur astronomers often have contests to see who can spot the first "slice" of the moon after the new moon phase. A gem of a game could also be made out of finding the smallest "slice" of the moon. It will be found around sunset.)

HOW IT LOOKS TO EARTHLINGS

FIRST QUARTER

13. The moon continues to wax until one fourth of it is seen by earthlings. This is the first quarter of the moon. Sketch this.

HOW IT LOOKS TO EARTHLINGS

WAXING GIBBOUS

14. The moon will continue to wax or grow in the waxing gibbous phase. Make another sketch.

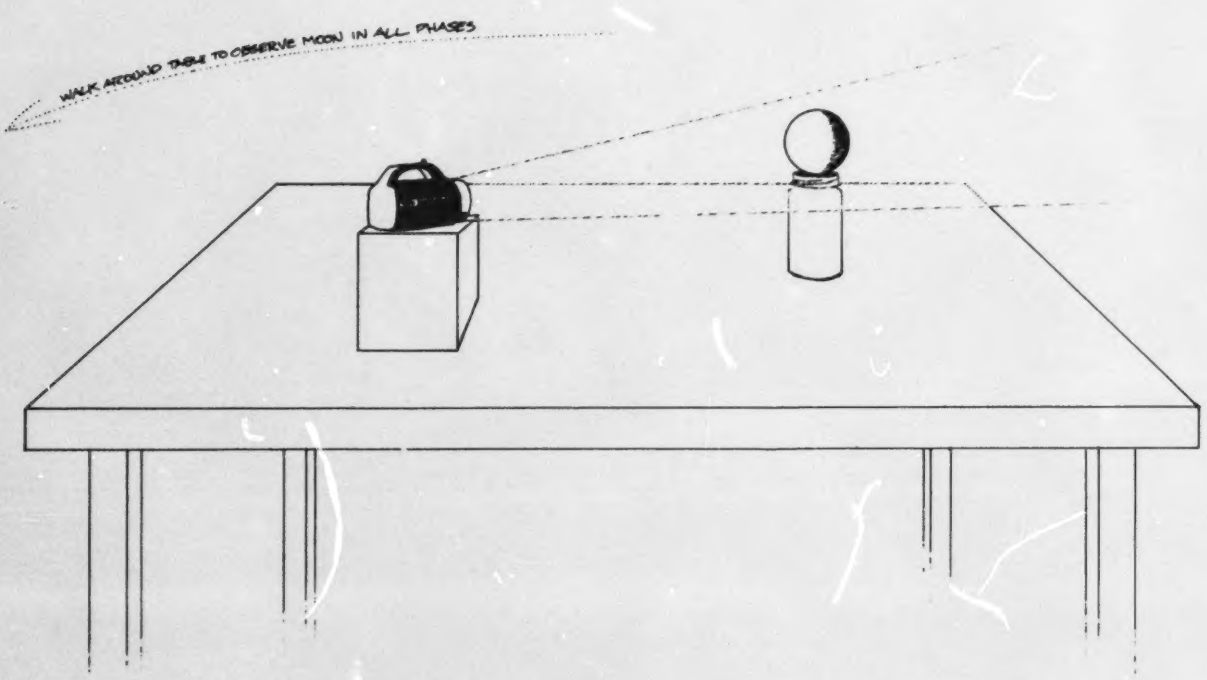
HOW IT LOOKS TO EARTHLINGS

Return to the full moon stage. Sketches of each cycle of the moon should have been made. Write the proper date by each of the sketches.

15. What is a lunar month?

16. How many days does a lunar month consist of?

17. What is earthshine?



Title: Sun: Measuring Its Size - I

Materials: A circle, drawn on a 3" x 5" card, which measures one centimeter in diameter; a piece of an aluminum drink can in which a pinhole has been made; and a sunny day (Note: An aluminum drink can is easily cut with scissors and then punctured with a nail. The hole should be about one millimeter in diameter.)

Procedure: The diameter of the sun can be determined by allowing light to pass through a pinhole and project onto a 3" x 5" card. By knowing the distance to the sun, by measuring the distance from the pinhole to the card, and by measuring the diameter of the image on the card, a proportion can be used to determine the diameter of the sun.

1. Mount the piece of the drink can on the end of a meter stick.

2. On a clear day, line up the meter stick and the piece of aluminum drink can so that the shadow of the metal falls on the card, with the spot of sunlight inside the circle drawn on the card. (Note: This is done **without** looking at the sun. Watch the shadow instead.)

3. Next, move the card along the meter stick until the light just fills the one centimeter circle. Call this circle the "S" measurement.

4. What is the distance between the pinhole and the card? Call this the "R" distance.

5. By using a simple proportion, the diameter of the sun can be determined if the distance from the earth to the sun is known. (Note: You will have the sides of similar triangles.)

$$\frac{\text{S (1cm diameter of the image on the card)}}{\text{R (Distance from the pinhole to the card)}} = \frac{\text{Diameter of the sun (km)}}{\text{Distance from pinhole to sun (km)}}$$

   To find the diameter of the sun, use either 149,000,000 kilometers or 93,000,000 miles as the distance to the sun.

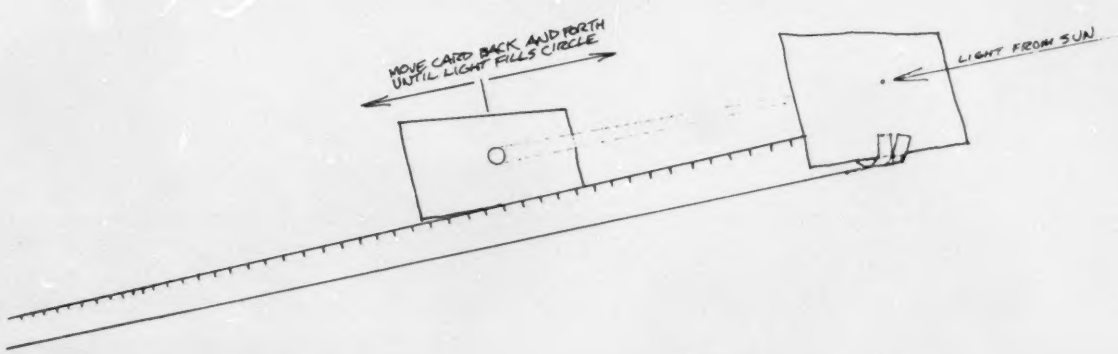
6. What is the diameter of the sun using these figures? The earth to sun distance varies slightly during the year, but the variation cannot be detected with this apparatus.

7. Now use the measurements to find the angular diameter of the sun in degrees.

$$\frac{S}{R}(57.3 \text{ degrees}) = \text{Angular diameter of the sun}$$

8. What is the angular diameter of the sun? The angular diameter of the sun is approximately 0.5 degrees. This figure varies due to the monthly changes in the distance from the earth to the sun.

The sun and moon have almost the same angular diameter as measured from the earth, even though these two celestial bodies are thousands of kilometers apart. It is due to this same angular diameter that we have solar eclipses.



Title: Sun: Measuring Its Size - II

Materials: A first surface mirror, a movie screen or a piece of poster paper, and a sunny day (Note: A regular mirror may be used, although it produces a double image.)

Procedure:

1. Using an opaque material, mask a first surface mirror. Leave a hole which has a diameter of one centimeter or less. Remember: the smaller the opening, the better the resolution, but the fainter the image.

2. Place the mirror in a position so that it reflects the sunlight. By doing this, an image is formed on the movie screen, which has been placed in the shade. Secure the mirror with a ring stand and burette clamp, or some other innovative device. (Propping the mirror on books which have been placed on a table, ledge, or the ground may work fine.)

3. Measure the diameter of the sun on the movie screen. Call this the "S" distance. This measurement will have to be made quickly because as the earth turns, the image moves. The longer the distance between the mirror and screen, the faster the image moves.

4. Now measure the distance from the first surface mirror to the screen. This is the "R" distance.

5. By using a simple proportion, the diameter of the sun can be determined if the distance from the earth to the sun is known.

$$\frac{\text{S (Diameter of the image of the sun on screen)}}{\text{R (Distance from mirror to screen)}} = \frac{\text{Diameter of the sun (km)}}{\text{Distance from mirror to sun (km)}}$$

6. Using 149,000,000 kilometers as the distance to the sun, determine the diameter of the sun.

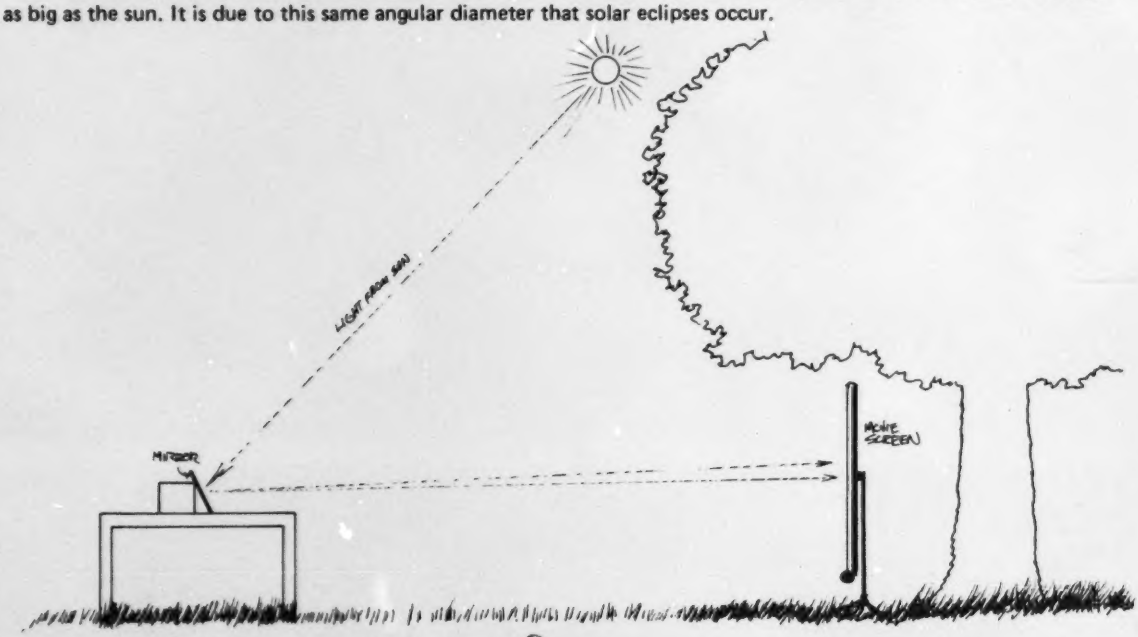
7. The distance from the earth to the sun varies during the year. During which month is the earth closest to the sun? (Note: It is not during the summer.)

8. Using these measurements, find the angular diameter of the sun in degrees.

$$\frac{S}{R}\,(57.3 \text{ degrees}) = \text{Angular diameter of the sun}$$

9. How does this figure compare with the one determined in "Sun: Measuring Its Size—I"? Was it around 0.5 degrees?

The sun and the moon have approximately the same angular diameter when measured from the earth, even though these bodies have vastly different linear ("actual") sizes. The moon is much smaller, but also much closer, so it looks as big as the sun. It is due to this same angular diameter that solar eclipses occur.



Title: Binocular or Refractor Projection of the Sun

Materials: A pair of binoculars, a piece of cardboard, a sheet of 8" x 11" paper, and a clear day

Procedure: Sunspots may be observed and recorded if sunlight is projected through a pair of binoculars onto a sheet of paper (8" x 11").

1. With tape, secure a pair of binoculars to a camera tripod. If a tripod is not available, use a burette clamp attached to a ring stand. This may be borrowed from a high school chemistry lab. In case that none of this equipment is available, the binoculars may be propped on books which have been placed on a window ledge. Regardless of the equipment used, the binoculars must be firmly fixed in place so that they cannot be jarred. However, due to the earth's rotation, minor adjustments will have to be made.

2. Before going outside, cut a piece of cardboard with a hole in the center so that it fits snuggly around one of the eyepieces (the small lens of the binoculars). The cardboard will allow a shadow to be cast on the piece of 8" x 11" paper.

3. Take the apparatus outside on a clear day. Point the binoculars toward the sun **without** looking through them. Before placing the cardboard over one of the eyepieces, position the binoculars properly by watching the shadow cast on the piece of paper that has been placed several inches behind the eyepiece of the binoculars.

4. When the apparatus is positioned correctly, the objective (the large lens of the binoculars) is closest to the sun. Fix the cardboard around the eyepiece and place a piece of paper (8" x 11") close to the eyepiece. When everything is in the right position, the bright image of the sun will be in the center of the shadow made by the piece of cardboard attached to the binoculars.

5. Move the piece of paper back and forth until the image of the sun is the proper size for optimum viewing. The distance of the paper from the binoculars determines the size of the image and its brightness. For the final adjustment, focus the knob on the binoculars until there is a sharp image of the sun. The proper adjustments will have been made when the edge of the image is as sharp as possible.

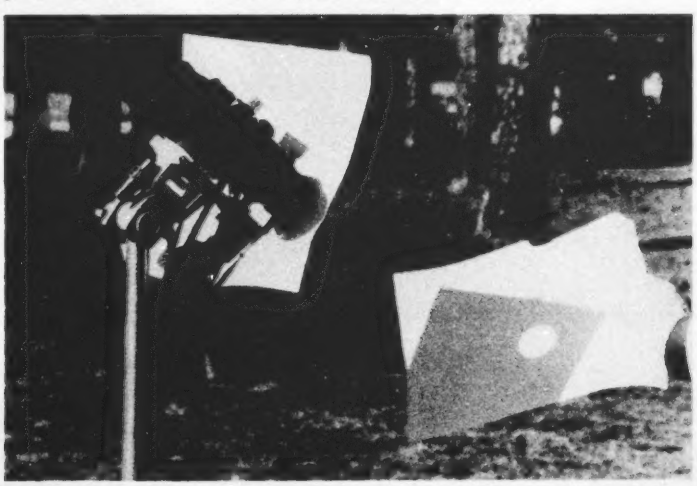
6. The little black areas that may appear on the image of the sun are sunspots. Sunspots come and go, so if none are seen, wait a few days and try again. With persistence, some will eventually be spotted.

   Although this procedure is an easy way to observe sunspots, remember that they may not always be seen. Studies of sunspot cycles indicate that they peak about every 11 years. Locate a good reference book that tells of recent data collected on sunspots with respect to weather and radio waves.

7. Draw the image of the sun and the positions of the sunspots on a piece of paper.

8. Repeat this activity for the next few days until the path made by the sunspots across the face of the sun can be determined. From this, you should be able to determine if the sun is rotating on its axis. This is also an excellent way to observe a solar eclipse.

CAUTION: Do not look at the sun through the binoculars. This will injure the retina of the eye.



Title: Moon Illusion

Materials: A full moon, a piece of dark glass or several negatives, and a ruler

Procedure: A full moon looks very large on the horizon, but relatively small when it is high overhead. This is just an illusion. Upon closer examination, it is found that the moon is the same size on the horizon as it is when high in the sky.

There are several ways to demonstrate that the "moon illusion" is a real physical occurrence:

1. View the moon through a piece of dark glass so that only a small amount of the horizon is visible. If possible, try eliminating the horizon.

2. View the moon upside down either by bending over and looking between your knees, or lying down on your back on a table with your head hanging off the edge.

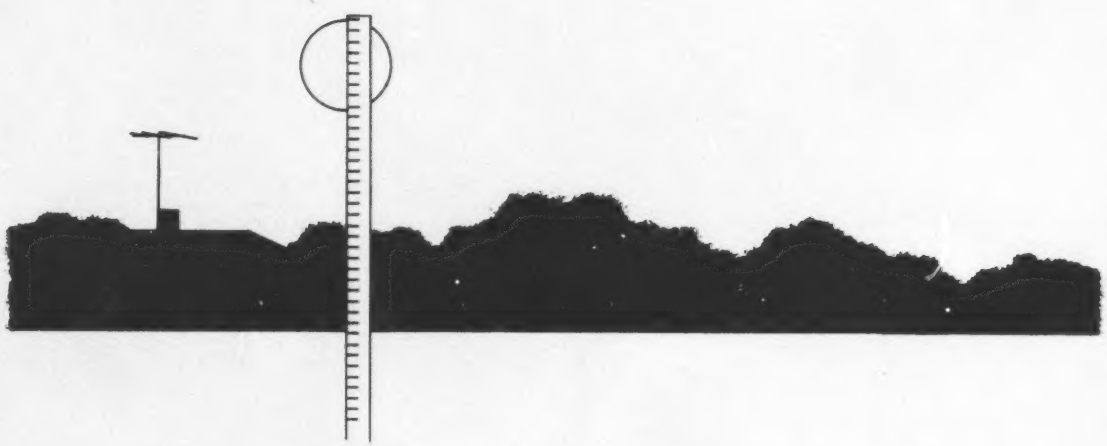
3. Use a ruler to measure the diameter of the moon. This can be done by holding a ruler at arm's length in front of you.

    a. Make a measurement when the moon is on the horizon.

    b. Make another measurement later when the moon is high in the sky.

    c. Compare these measurements.

The "moon illusion" has been explained as being caused by the magnification of light as it passes through the atmosphere; however, this activity will show the students that this explanation is not true. So far, there has not been an agreement as to the cause of the "moon illusion," but one thing is clear: **The enlarged moon is just an illusion.**



Title: Sundial: Making Your Own

Materials: A sundial apparatus, a compass, and poster paper

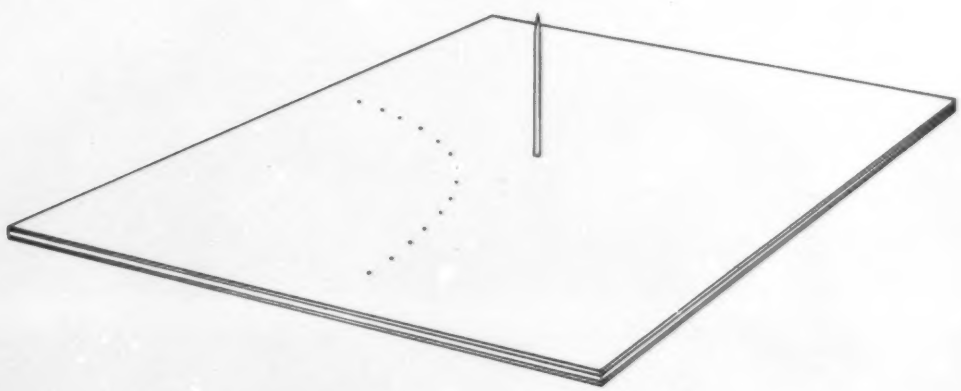
The following materials are needed to make a sundial apparatus: a piece of plywood (45 centimeters square) and a dowel (10 centimeters).

Sharpen the end of a dowel to a point. Secure the dowel to the center of the plywood with a screw or nail. The dowel will be the gnomon, which is the pointer of the sundial. A temporary sundial apparatus could be made with corrugated cardboard and a pencil; however, since this apparatus is used in the activities "Analemma" and "North-South Line: Meridian," it is recommended that a permanent one be made.

Procedure: The sundial is the oldest known instrument used to measure time. It consists of a square board, which is the face, and a dowel called the gnomon, which is perpendicular to the face. The sundial uses the shadow cast by the sun as it moves from east to west. However, you will not use it to tell the time; instead, you will use it to study the motion of the sun.

1. Locate a place in the schoolyard free of trees—a place where the sun shines throughout the day.
2. Cut a piece of poster paper the size of the sundial apparatus. Cut a hole in the center and place it over the apparatus.
3. Mark a north-south line through the center of the piece of poster paper.
4. On a sunny day, place the sundial apparatus in the spot you have selected in the schoolyard. Align the north-south direction with the magnetic compass. (Note: A magnetic compass works well in South Carolina because the magnetic deviation is only two or three degrees.)
5. In the morning begin marking the position of the shadow cast by the gnomon. The position should be marked every 20 minutes during the school day. By each mark, indicate the time using Eastern Standard Time.
6. At the end of the day, draw a smooth curve through all the marks made. This should give you the motion of the sun during a day.
7. Repeat this activity at monthly intervals on the same piece of poster paper. After a few times you should be able to estimate the path of the sun.

   Note: Try using the shadow of the school flagpole. Perhaps the position of the shadow could be predicted before it is actually marked. Small pegs could be placed in these positions for 20-minute intervals during the day. It may be even more interesting to compare the motion of the sun using both the sundial apparatus and the school flagpole.



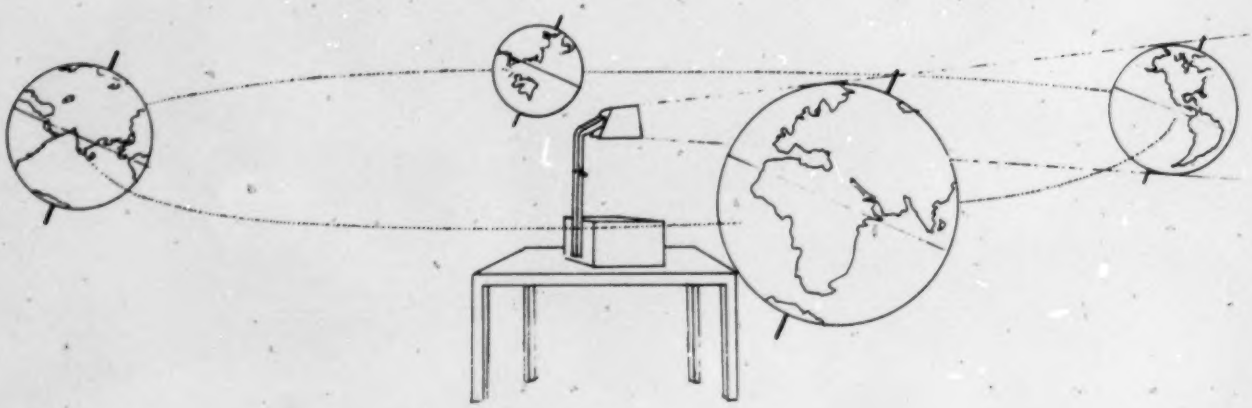
Title: Seasons and Polar Circles

Materials: A strong light source; a globe of the earth; and the words *summer, autumnal equinox, winter,* and *spring equinox* written on cards with the appropriate dates (Note: The light made by an overhead projector is excellent.)

Procedure: This demonstration will illustrate how seasons are determined not by the distance of the earth from the sun, but by the angle that sunlight strikes the earth.

1. Place a strong light source (like an overhead projector) in the center of the room. The lamp should be turned during the demonstration so that light strikes the globe at all times.
2. Direct the light source onto the globe, which is tipped about 23.5 degrees.
3. Keep the axis of the globe pointing toward the same point in space, as shown in the sketch.
4. Keep the axis of the globe pointed in the same direction, toward the North Star, as the globe is carried counterclockwise around the light source. Remember that the North Star is in a fixed position about 500 LY (light years) above our north axis.
5. Stop at each quarter turn of the orbit to determine which season is represented. Have a student stand holding the proper card to indicate each season as the orbit continues.
6. By slowly spinning the globe, day and night can be demonstrated.
7. Go back to the summer position and slowly spin the globe to demonstrate how the North Pole and the region around it is illuminated all day, yet it receives very little sun.

Everyone should understand by this demonstration that it is the angle of the sun striking the earth and not the distance of the earth from the sun that causes the seasons. Also, everyone should be able to see how each polar circle receives light all day long for one day out of the year.



Title: North-South Line: Meridian

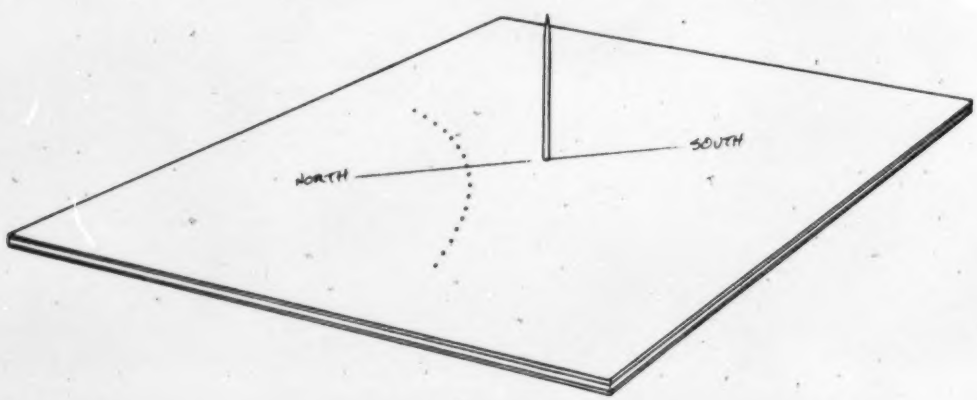
Materials: A sunny day; the apparatus used in "Sundial: Making Your Own" and poster paper; or a pencil and a piece of 8½" x 11" paper

Procedure: To find the meridian, mark the end of a shadow cast by a gnomon or pencil at definite intervals. Either the apparatus made for the activity "Sundial: Making Your Own" or a pencil driven in the ground over a piece of 8½" x 11" paper may be used.

1. Place either apparatus in a spot in the schoolyard so that the sun shines on it all day and is free from shadows.
2. Put the poster paper over the sundial apparatus or drive the pencil in the ground over the piece of 8½" x 11" paper so that the tip of the 10:00 a.m. shadow falls on the paper.
3. Mark the end of the pencil's shadow on the paper every 15 minutes from 10:00 a.m. to about 2:00 p.m. Make sure that the paper does not move in any direction.
4. Write the time next to each mark as it is made.
5. After all points have been made, bring the paper indoors and draw a smooth curve through the points.
6. With a straight line, connect the point on the curve that is closest to the hole made by the gnomon. This is the North-South Line.

   The meridian is the line on the sky that is directly above the North-South Line. The sun is on the meridian when the shortest shadow is produced. The time that the sun passes over the meridian is the *local noon.*
7. What is the local noon for your school? For accuracy, interpolate the time.
8. If you are on Eastern Standard Time, is local noon before or after 12:00 noon by your watch? Hint: Are you in the middle of your time zone?
9. How much difference should being on daylight-saving time make?

   If you find it hard to remember how to change your watch when we switch from EST, to DST then remember the jingle "Spring forward, fall back." If you are on DST can you see from this jingle how to obtain local standard time from your watch?
10. What is meant by a.m. and p.m.?
11. What do the following abbreviations represent: EST, CST, MST, PST, GMT, and Z (pronounced *Zulu*)?



Title: Analemma

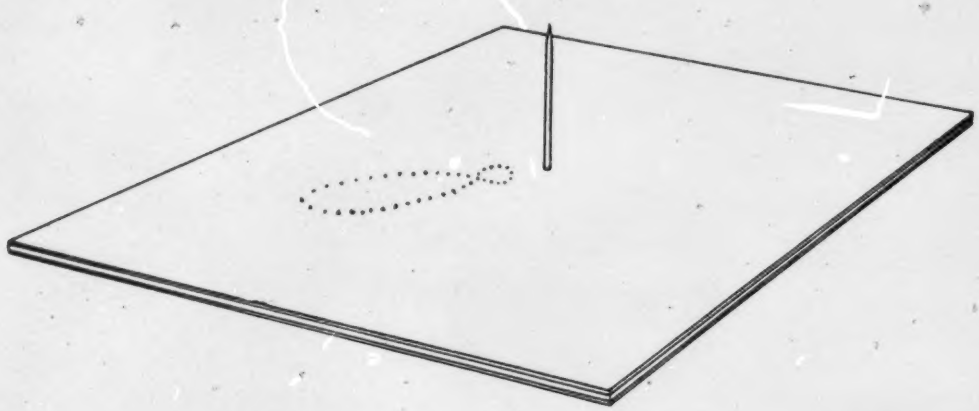
Materials: The sundial apparatus made for the activity "Sundial: Making Your Own," poster paper, and a sunny day

Procedure: In the shape of a figure-8, an analemma is a graphic representation of the changing positions of the sun during a year. Although the position of the sun must be plotted each week for a year in order to complete the analemma, an interesting portion can be made during a school term.

It is important that this activity be done at precisely the same time each day. When the time changes from Daylight-Saving Time to Eastern Standard Time and vice versa, make the proper allowances. By using the same time each day, the analemma will illustrate that the sun has an annual north-south movement back and forth in the sky. This oscillation of the sun accounts for the seasons.

1. Align the sundial apparatus with the north-south axis by using a compass.
2. Select a day that will be convenient each week. (Note: If a measurement cannot be made because of the weather, another day of the week will be fine as long as it is made at the same time of day.)
3. Select a location in which to place the sundial apparatus that will be clear of trees, as the position of the sun shifts from one season to another.
4. Collect the data by making a weekly mark on the paper indicating the position of the shadow made by the tip of the gnomon.
5. By each mark, indicate the date.
6. Connect the marks that have been made each week.
7. How soon does this resemble a figure-8?
8. Look in the school library for a globe. Compare your tracing to the analemma found on most globes.

A photographic record of an analemma can be made in almost this same way. A student may want to try this activity. Instructions can be found on page 536 of **Sky and Telescope** (June 1979).



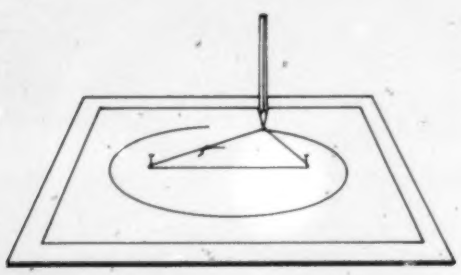
Title: Ellipses and Orbits

Materials: String, corrugated cardboard, two straight pins, and a piece of white paper

Procedure: One of Kepler's laws states that each planet has an elliptical orbit. Kepler came up with this theory by plotting the orbit of Mars, his assignment when he was invited to become one of Tycho's assistants at his new observatory in Prague.

1. Place a sheet of paper over the corrugated cardboard.
2. Press two straight pins, about five centimeters apart, through the paper into the piece of corrugated cardboard.
3. Cut a piece of string three times the distance between the pins, plus enough for a knot.
4. Tie a knot to form a loop and lay the loop on the paper so that it encloses the two pins.
5. Place a pencil inside the loop and stretch the loop taut against the pins. Draw an ellipse around the two pins by keeping the pencil point as far from the pins as the string will allow.
6. Remove the pins and string.
7. Draw the major axis through the two pinholes. This will be the longest distance across the ellipse.
8. Draw the minor axis through the shortest distance across the ellipse. It will be perpendicular to the major axis at its midpoint.
9. Label the two foci. These are the holes left by the pins.
10. Sketch the sun at one focus. The ellipse is the orbit or path of a planet.
11. Label the perihelion on your drawing. This is the point on the orbit closest to the sun. It is at one end of the major axis.
12. Label the aphelion on your drawing. This is the point farthest from the sun in the orbit of a planet. It also is at one end of the major axis.

Kepler discovered that the orbit of Mars is elliptical and that the sun is at one focus, with the other empty. He plotted the orbits of the other planets and determined that they are also elliptical. Kepler then formulated his *Law of Elliptical Orbits*: Each planet moves in an orbit around the sun, called an ellipse. The sun is located at one focus of the ellipitical orbit.



Title: Eccentricity of Orbits

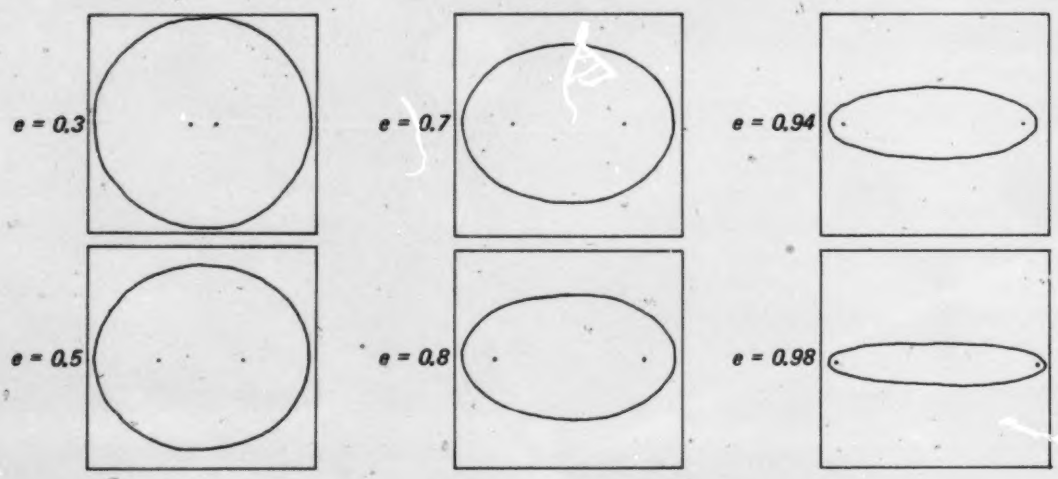
Materials: Paper plates, string, corrugated cardboard, two straight pins, and a piece of paper

Procedure: The eccentricity of a circle is equal to zero. The more oval an orbit becomes, the greater the eccentricity. The greatest possible eccentricity of an ellipse is one.

1. Hold a paper plate so that the students are facing it.
2. Tip the plate slightly so that it can be seen as a slight oval. Remember, the eccentricity of a circle is zero. Estimate the eccentricity for each shape by comparing them to the diagrams.
3. Tip the plate more and predict the eccentricity of this orbit.
4. Continue to tip the plate until it appears to be a straight line. What is the eccentricity now?
5. Place a piece of paper over the corrugated cardboard.
6. Draw a line through the center of the paper lengthwise. This is the major axis of the ellipse.
7. Press two straight pins, about one or two centimeters apart, through the paper into the corrugated cardboard.
8. Cut a piece of string three times the distance between the pins, plus enough for a knot.
9. Tie a knot to form a loop and lay it on the paper so that it encloses the two pins.
10. Place a pencil inside the loop and stretch the loop tight against the pins. Draw the ellipse around the two pins by keeping the pencil point as far from the pins as the string will allow.
11. Leave one pin in place. Put the other pin farther out on the major axis. The eccentricity of this orbit will be greater than the last. Estimate the eccentricity of these orbits by comparing them to the diagrams below.
12. To measure the eccentricity of the orbit, use this formula:

$$\text{eccentricity} = \frac{\text{c (the distance between the two foci)}}{\text{a (the length of the major axis)}}$$

13. Look up the eccentricities of the planetary orbits. Are these orbits very elliptical?
14. Which two planets have the most elliptical orbits?



Title: Planetary Spacing: *Titius-Bode Rule*

Materials: A chalkboard and a meter stick

Procedure: The *Titius-Bode Rule* can be used as a scheme for demonstrating the spacing between the planets in our solar system. The approximate distance from the sun to each of the planets can be found by using this formula: Use a progression of numbers (0, 3, 6, 12 . . .), add 4 to each number, and divide by 10.

Titius discovered this rule or *law* and Bode made it famous by using it to search for the missing planet between the orbits of Mars and Jupiter. Many astronomers searched this area of the sky for the missing planet. Ceres was found in this region in 1801. Not long after this discovery, several other minor planets were discovered which are sometimes called asteroids or planetoids.

TITIUS' PROGRESSION	PLANET	PLANET'S ACTUAL DISTANCE (AU)
(0+4)/10=0.4	Mercury	0.387
(3+4)/10=0.7	Venus	0.723
(6+4)/10=1.0	Earth	1.000
(12+4)/10=1.6	Mars	1.524
(24+4)/10=2.8	(Asteroid belt)	(Ceres)
(48+4)/10=5.2	Jupiter	5.203
(96+4)/10=10.0	Saturn	9.539
(192+4)/10=19.6	Uranus	19.18
	Neptune	30.6
(384+4)/10=38.8	Pluto	39.4

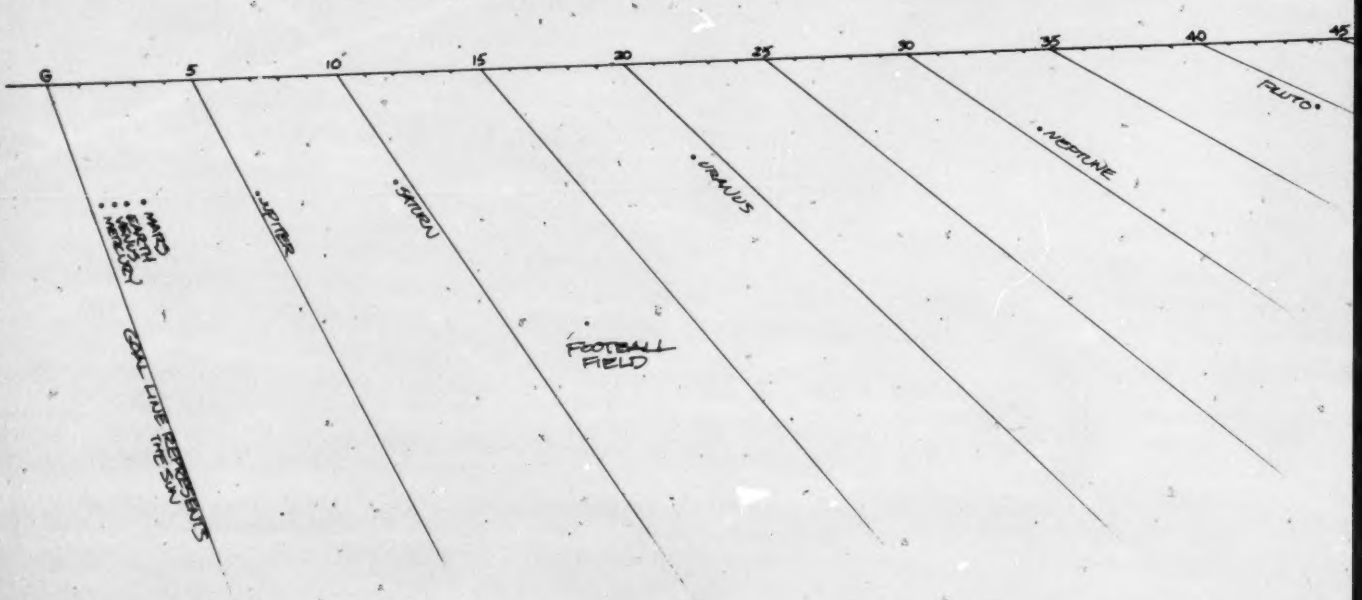
The units for these distances are astronomical units. What is an astronomical unit?

By representing the astronomical unit with a smaller unit, the proper spacing between the sun and planets can be demonstrated to scale in the classroom or on a football field.

a. By using centimeters or inches, the spacing between the planets can easily be illustrated on a chalkboard.

b. By using feet, the spacing between the planets can easily be illustrated in a classroom. Use pieces of curved string as sections of the orbits.

c. By using yards, the spacing between planets can be demonstrated on a football field.



Title: Eclipses

Materials: A lightbulb in an old lamp, a ball about 25-30 millimeters in diameter, and a meter stick

Procedure: The simulation of an eclipse is a classroom activity which will enable students to better understand this phenomenon. A lightbulb represents the sun and a small ball, which has been mounted on a pencil or placed on top of a jar, represents the earth.

1. Mount a small ball on a pencil or jar about a meter from the lighted bulb.

2. Have a student close one eye and line up the ball with the other. Move the ball closer to the student's eye until the bulb disappears. This is a simulation of a total eclipse at mid-cycle.

3. Move the ball from right to left across the bulb to see the entire cycle of a total eclipse. Return the ball to mid-eclipse.

4. Keep the ball in position and have the student move his eye slowly away from the ball until the lightbulb is clearly seen around the ball. This is a simulation of an annular eclipse at mid-cycle. The Latin word *annulus* means *ring*.

5. To see the entire cycle, have the student keep his/her eye in place and move the ball from right to left across the bulb.

6. Now move the ball enough so that it is slightly off center. Various partial eclipses will be seen as the ball is moved from right to left. Several eclipses can be demonstrated by varying:

   a. the distance from the earth to the moon

   b. the alignment between the centers of the moon and the sun

Title: Umbra and Penumbra

Materials: Two floodlights or two 150-watt lightbulbs in old lamp bases

Procedure: The motion of the earth and moon results in interesting events called eclipses. At certain times the earth, moon, and sun line up such a way that they cast shadows. When the light of the sun is blocked, a solar eclipse occurs; when the moon is darkened, a lunar eclipse occurs.

When eclipses occur, two shadows of different intensities are formed. All the light is blocked when we are in the umbra, which is the total eclipse region. The penumbra is the area where only part of the light is blocked. This is the partial eclipse region.

A floodlight shining on a student will produce a shadow. However, when another lamp is turned on, the shadow has regions of different intensities. The difference between these regions, the umbra and penumbra, can be demonstrated in the classroom. The darker shadow is the umbra, while the lighter shadow is the penumbra.

1. Have a student stand about two feet from a clean blackboard or a wall. Make certain that the student is far enough away from the blackboard to cast two shadows that overlap each other.

2. Place a floodlight on each side of the student, about two meters (two yards) away at a 45 degree angle.

3. Turn off the regular lights in the room and turn on the floodlights.

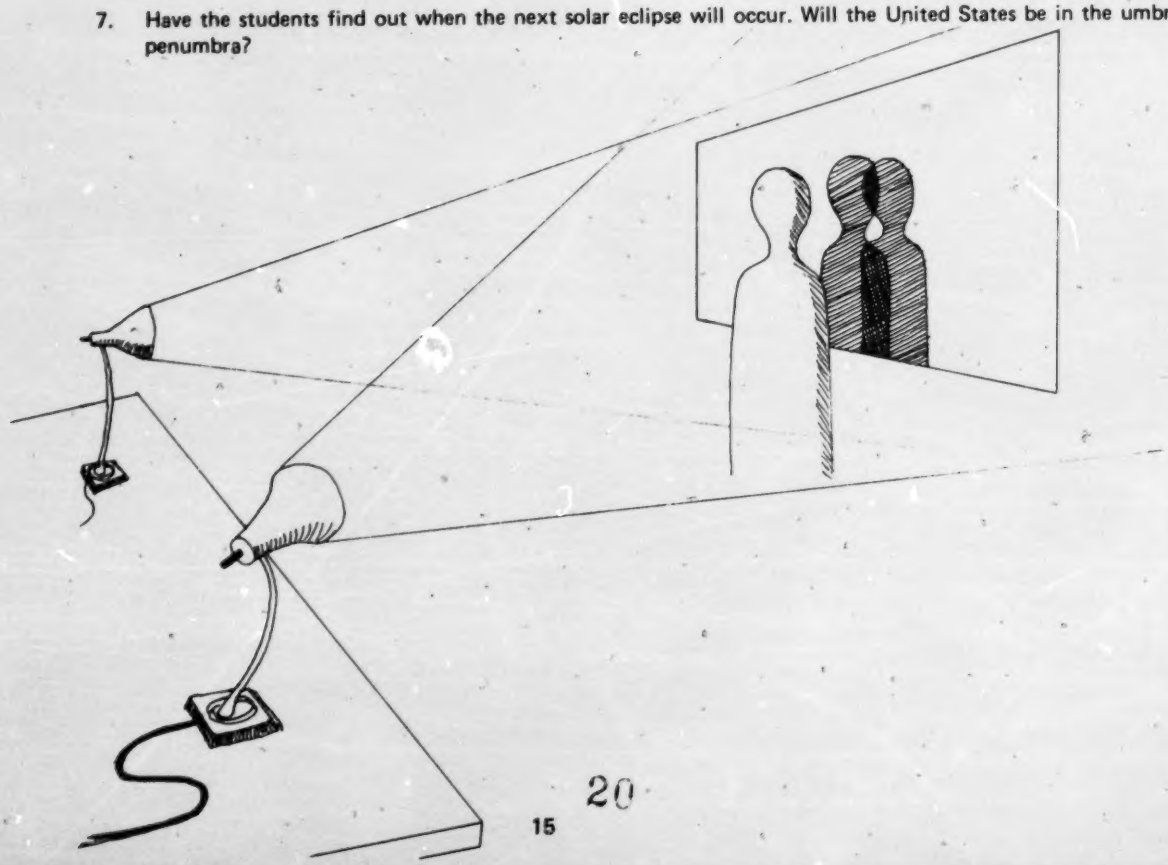
4. Have a student place his/her head in the penumbra. Can this student see both lightbulbs?

5. Next, have another student place his/her head in the umbra. Can this student see both lightbulbs?

The same effect is produced by the sun shining around the earth or moon during an eclipse. The student looking from the penumbra could see only one lightbulb. The earthlings in this position are in the partial eclipse region. The student that was in the umbra could not see either lightbulb. This time the earthlings are in the total eclipse region.

6. Have the students find out when the next lunar eclipse will be for this region. Will your school be in the umbra or penumbra?

7. Have the students find out when the next solar eclipse will occur. Will the United States be in the umbra or penumbra?



Title: Diagram: Solar Eclipse

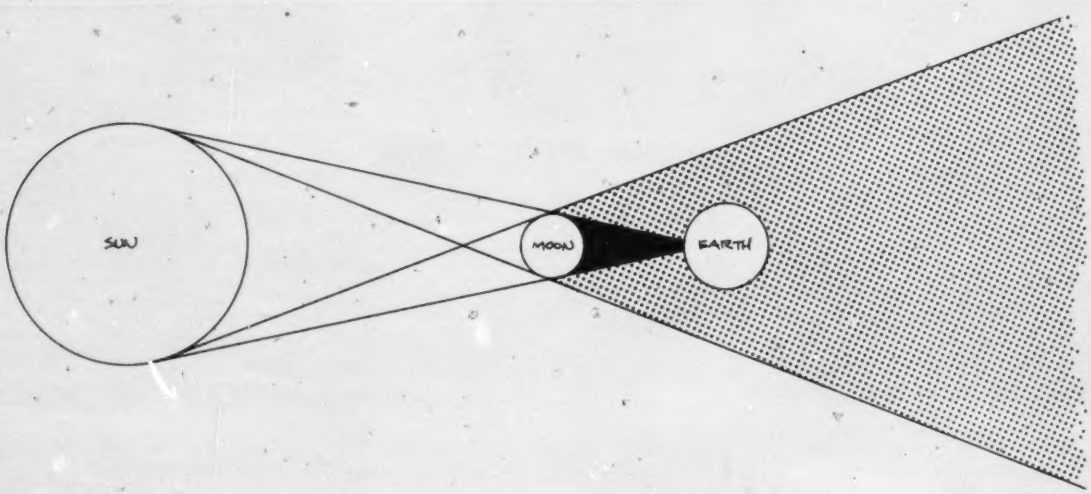
Materials: A Kerr or Mason jar lid, a dime, a quarter, a sheet of 8½" x 11" paper for each student, and a ruler

Procedure: To illustrate the solar eclipse, a sun ray diagram will be drawn. Several important principals can become clear by drawing the positions of the sun, moon, and earth during a solar eclipse. The difference in intensities of the shadows of the umbra and penumbra can be made clear with this type of a diagram. Also, the same angular diameter of the sun and moon as seen by earthlings is best illustrated with a diagram. This same angular diameter causes the eclipse phenomenon.

1. Use a Kerr or Mason jar lid to outline the sun on the side of the 8½" x 11" paper.
2. Use a quarter to outline the earth. The distance between the center of these two bodies is 18 centimeters.
3. The moon can be outlined with a dime. The distance from the center of the moon to the center of the earth should be about five centimeters.
4. Next draw a line from the top of the sun to the top of the moon. Even though there are many light rays coming from the sun, this line will represent one ray of sunlight.
5. Another sun ray should be drawn from the bottom of the sun to the bottom of the moon.
6. Draw a ray from the top of the sun to the bottom of the moon.
7. A sun ray should be drawn from the bottom of the sun to the top of the moon.
8. The area where both shadows overlap is the umbra. Shade this region dark. Earthlings in this area would see a total solar eclipse.
9. Shade the other areas lighter. This is the penumbra. Earthlings here would see a partial eclipse.
    a. If the distance between the moon and earth varies, then the umbra may not reach the earth.
    b. If the moon is slightly off center, either a partial eclipse will occur or no eclipse at all.

Remember: For a total eclipse to occur, the angular diameter of the sun and moon must be the same and these bodies must be perfectly lined up.

Extra Activity: Make a sketch of the sun, moon, and earth where the umbra does not reach the earth.



Title: Diffraction Grating Spectroscope

Materials: Replica gratings (transmission diffraction) which can be obtained from any science catalogue (very inexpensive), a paper towel tube, a piece of aluminum foil about 4" x 4", a light source (an incandescent lightbulb), and a darkened room

1. Prepare the spectroscope by covering the end of a paper towel tube with a 4" x 4" piece of aluminum foil and cutting a narrow slit (2-3 millimeters) in the center of the foil so that a little light can enter the tube. Secure it with scotch tape if necessary. An alternate method of making a spectroscope would be to cut a narrow vertical slit (2-3 millimeters) in a tin can and then place the can over a lightbulb.

2. Hold the replica grating next to your eye. Place the tube next to the grating so that the slit in the other end is pointed toward a lightbulb.

3. Now rotate only the replica grating until a continuous spectrum appears inside the tube. (Although this is not recommended, the replica grating could be fastened to the tube to make a permanent spectroscope.)

   When light passes through the replica grating, a continuous band of colors ranging from red to violet appears. An easy way to remember the color sequence is by remembering the fictitious name of Roy G. Biv, an acronym for the colors of the continuous spectrum. Starting with the longest wavelength and ending with the shortest, the sequence is as follows: red, orange, yellow, green, blue, indigo, and violet. The diffraction grating serves as a way to break up white light into different size wavelengths. A prism serves the same purpose, but it is more expensive than a replica grating.

4. It has been seen that an incandescent lightbulb produces a continuous spectrum. The presence of certain elements is indicated by a different sort of spectrum called an *emission spectrum.* Emission spectra may be found in some other common light sources. Try as many different light sources as possible.

   a. Fluorescent bulbs produce an emission spectrum (bright lines) superimposed on a continuous spectrum.

   b. Yellow street lights (found in parking lots and along some streets) indicate the presence of sodium by the yellow doublet.

   c. Security lamps (a $5/month blue light) indicate mercury by producing an emission (line) spectrum.

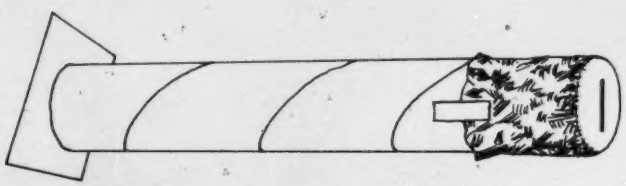
   d. Neon produces an emission spectrum.

   (Note: *Spectrum* is singular and *spectra* is plural.)

The spectra colors appear as lines because they are images of the slit in each color, and not because of something done by atoms. The types of atoms determine the colors that appear, but the spectroscope shapes the colors into lines. This can be proven quite easily by replacing the aluminum foil on the end of the spectroscope, and cutting a slit in some other shape—e.g., zigzag or trianglar. The "lines" of the emission spectrum examined now will be whatever shape chosen for the slit.

A continuous spectrum appears in the spectroscope when all of the colors are present. There is then an infinity of images of the slit, and they run together to produce a continuous spectrum. If the light source emitted all **except** a few colors, then the slit images of those colors would be missing. These would then be dark gaps in the otherwise continuous spectrum. This is a third type of spectrum called an *absorption spectrum* and is the kind that most stars produce.

Each element has characteristic spectral patterns. Think of these spectral colors in relation to fingerprints—everybody has a different set of fingerprints, just like each element has a characteristic set of spectral colors.



Title: Filters, Transmission

Materials: Colored transparent plastic filters (colored plastic packaging or filters ordered from a science supply company), a light source, and the spectroscope constructed for the activity "Diffraction Grating Spectroscope"

Procedure: Colored filters will be used to demonstrate the properties of transmission of light. Filters appear colored because they selectively remove colors from white light.

1. Set up the apparatus used in "Diffraction Grating Spectroscope." Observe the continuous spectrum of an ordinary incandescent bulb.

2. Place various filters over the slit and note which colors are transmitted.

COLOR OF FILTER	COLOR TRANSMITTED
red	
green	
yellow	
blue	
violet	

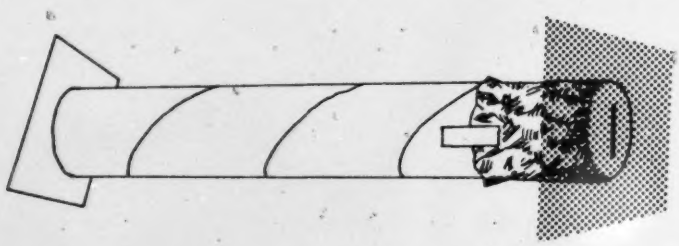
3. Where are the other colors? When white light passes through a piece of red cellophane, it emerges as red light. The red cellophane acts as a filter and cuts off all the colors but red. If white light passes through a blue filter, it becomes blue, and so on.

4. Now use two filters at one time. What are the colors that are transmitted?

COLOR OF FILTER	COLOR TRANSMITTED
red and blue	
red and green	
blue and green	

5. Are the colors absorbed by the filters? Some filters absorb all but one color and so appear to be the color that is not absorbed.

Each of the colors making up white light has a characteristic wavelength. Red has the longest wavelength and blue has the shortest. Each color has a different amount of energy—blue has the greatest and red the least. Energy and wavelength are inversely proportional. Of visible light, red has the longest wavelength, but contains the smallest amount of energy.



Title: Star Trails: Getting Them

Materials: Tri-X black and white or Kodacolor 400 ASA film, a camera that will take time exposure photographs, a cable release for the camera (preferably with a locking nut so that it can keep the camera shutter open without your holding it), and a clear, moonless night

Procedure: An excellent way to capture the movement of the heavens is by taking star trail photographs. This can be done by setting up the camera in an open field on a clear, moonless night and then taking time exposure photographs. Take one picture with the camera pointed toward the ecliptic and another with it pointed toward the pole star, Polaris.

1. Make a fixed support for the camera by using a tripod. A sandbag will also make an excellent support.

2. If the shutter on the camera has a time exposure, use a cable release. The time exposure can be for one minute, five minutes, ten minutes, or as much time as desired. If the camera is pointed at the North Star, one hour will produce an arc of 15 degrees.

Note: When the film is processed, it is wise to indicate *astronomy* or *star trails* in the section for special instructions. Indicate that the film be *developed only*—in other words, no prints. Darkroom attendants frequently do not see the tiny dots that stars make on the film. They may think that there is no picture and cut the film across the star trails. By having the film *developed only*, you will be able to have printed the ones you like.

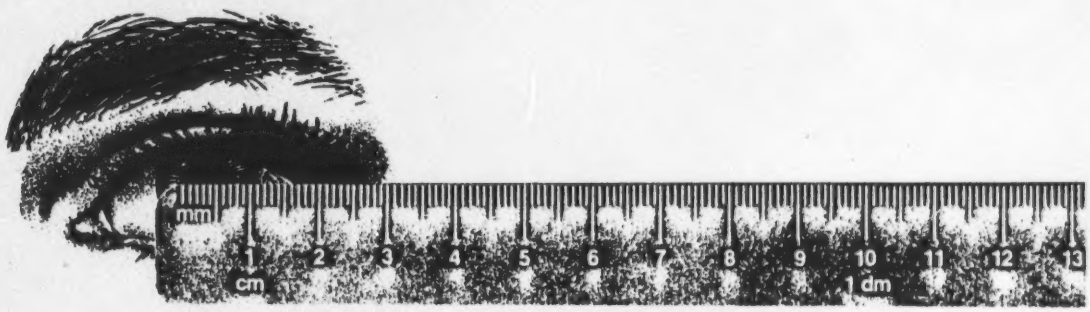
Title: Eye Response to Light: Pupil Size

Materials: One ruler for every two students

Procedure: Being able to recognize the characteristics of the eye helps students make astronomical observations. In this activity, students will measure the diameter of the pupil in the eye and determine the time it takes for the pupil to respond to changes in light.

1. Divide the students into pairs. One student will observe the other's pupil and take the measurement.
2. Dim the room for a few minutes.
3. Have one student measure the diameter of the other student's pupil.
4. Brighten the room greatly.
5. Take the measurement of the diameter of the pupil.
6. Repeat the procedure so the students can reverse roles. Allow time for measurements.

The time required for the eye to adapt to the dark increases with age. So, if possible, repeat the experiment with people of widely differing ages to see how age affects pupil response time.



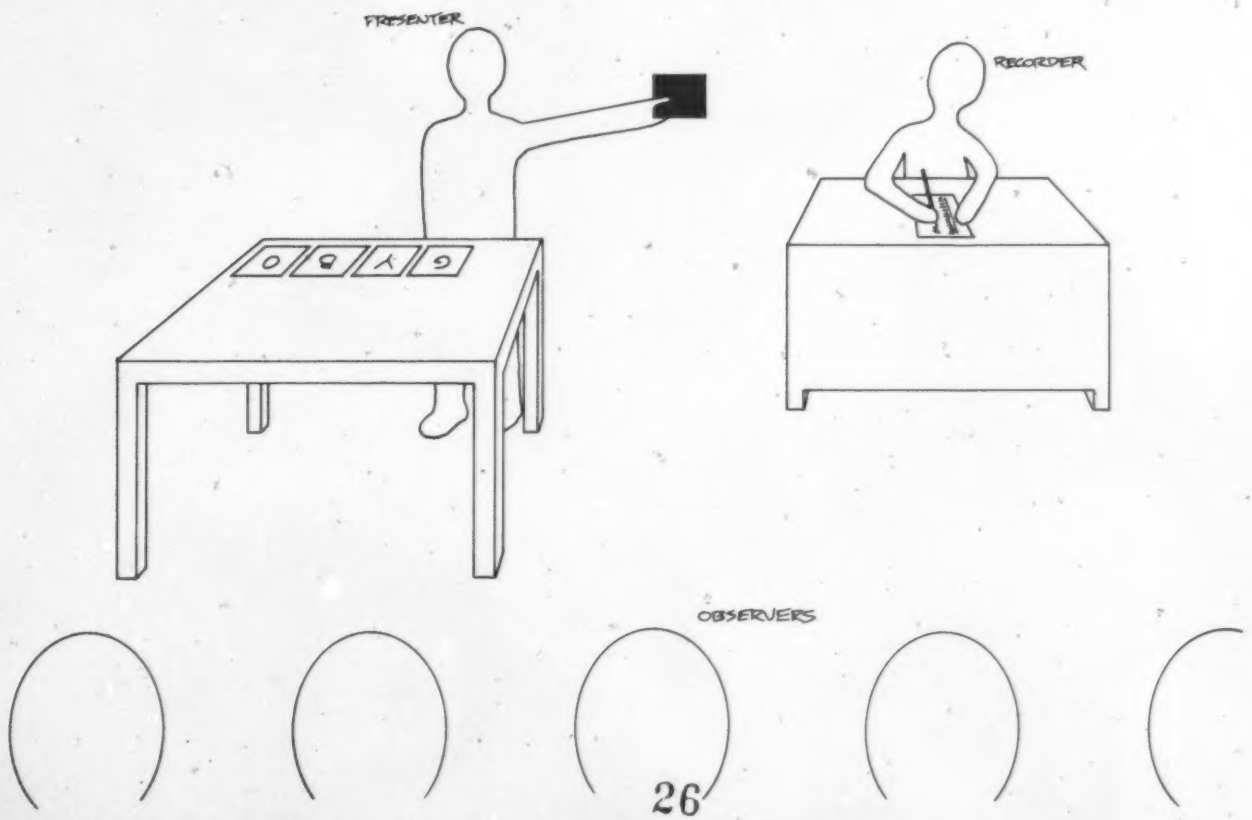
Title: Eye Response to Light: Color Sensitivity

Materials: Red, orange, yellow, green, and blue cards colored only on one side; a lamp; a lamp dimmer; and a darkened room

Procedure: By using different amounts of illumination on colored cards, it will be seen that when the amount of light is reduced, each color appears white. It is because of this same effect that most stars look white to the naked eye.

1. On the back of each card, write the appropriate capital letter for the color of that card (R, O, Y, G, or B). The card should not be colored on the back.
2. Select one student to present the cards and another to record the responses. The class will observe.
3. Darken the room as much as possible. Under full illumination have a student present one card at a time, with the colored side toward the class. The class can call out the color.
4. As this is being done, the recorder writes down the letter of the actual color from the back of the card. The recorder also writes down the response of the class. (Note: It is important that the class not know if its response is right until all tests are completed. Do not allow the class to see the letters written on the backs of the cards.)
5. Use the lamp dimmer to cut the light intensity in half. Repeat the procedure.
6. Again, use the lamp dimmer to cut the light intensity in half.
7. Continue reducing the light intensity in this way until the observers are clearly missing the colors.
8. Why do you suppose that most stars look white to the naked eye, even though they actually have many hues?
9. Does a person's age make any difference?

This activity should help students understand that many stars are classified as being red, orange, yellow, and blue, even though these stars appear white at first glance.



Title: PRESSURE: Atmospheric

Materials: A jar, a piece of cardboard, and an empty duplicator fluid can

Procedure: It is difficult to study atmospheric pressure directly because air cannot be seen and it cannot always be felt. However, the results of air pressure can be observed.

1. Fill a jar with water. If you are careful, you can fill it so that it is "lipping full." The water will then bulge above the rim.
2. Dampen a piece of cardboard, which is a little larger than the mouth of the jar.
3. Carefully invert the jar **exactly** upside down while holding everything in place. Then slowly remove your fingers from the cardboard.
4. Does the cardboard fall off?
5. Why does the cardboard stay in place?
6. What is holding the cardboard to the jar?

The results of air pressure may be seen another way—as it crushes a duplicator fluid can.

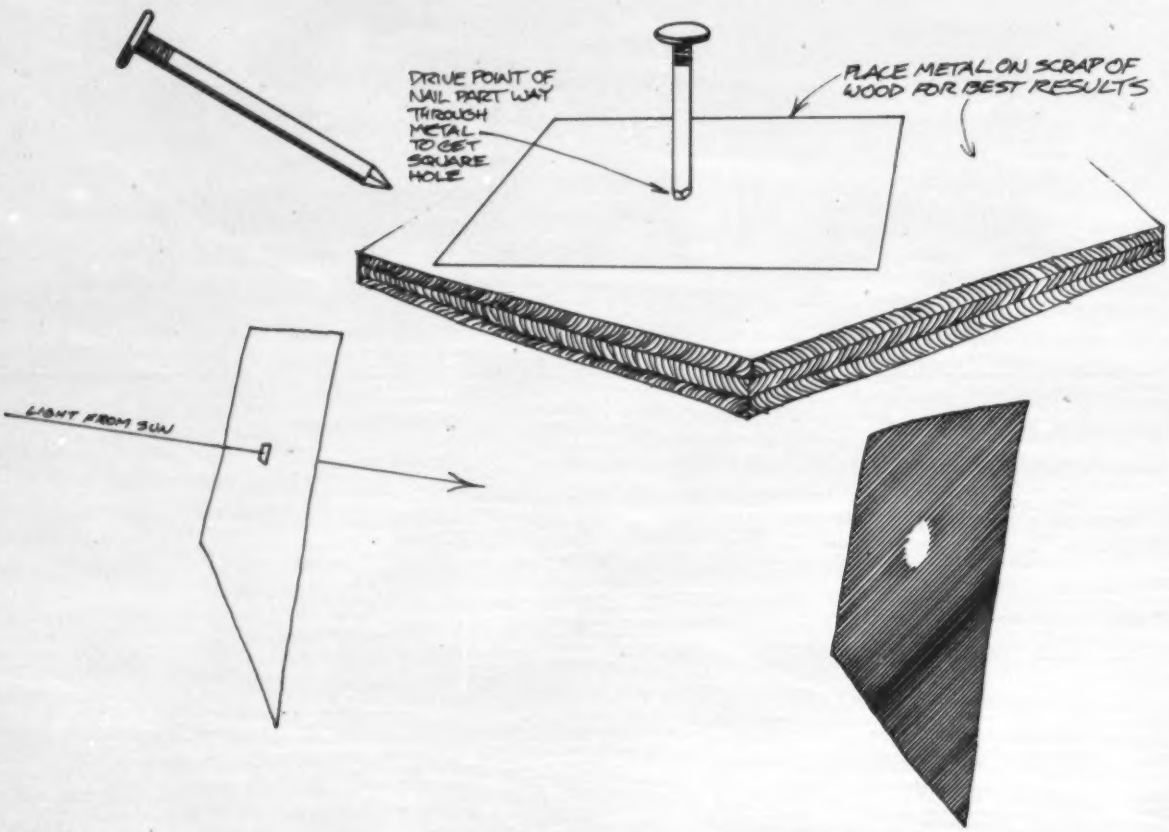
7. With water, thoroughly rinse an empty duplicator fluid can.
8. Place one-half to one inch of water in the bottom of the can.
9. Leave the cap off the can.
10. Place the can on a heat source and bring the water to a full boil.
11. Remove the duplicator fluid can from the heat.
12. Cap the can tightly.
13. Place the duplicator can in a cool place—the cooler the better—but in a spot where it can be seen. (A classroom desk is adequate.)
14. What happens to it?
15. What causes the can to crumple? When additional air is squeezed into a space, the pressure increases. When air is removed from a space, the pressure decreases. Pressure is dependent upon temperature and volume. By allowing the temperature to fall, the pressure inside the duplicator can decreases, thus removing the outward pressure that balances the inward pressure of the surrounding air. The thin metal which the can is made of is not strong enough to withstand the unbalanced external pressure, thus causing the can to crumple.

Title: Pinhole Projection

Materials: The same piece of equipment that was made for "Sun: Measuring Its Size—I," a white card, and a clear day (Note: This time, use the point of a nail to punch a square hole in the metal.)

Procedure: Light from the sun will be projected through a square hole. When the card is held close to the hole, the image will be in the shape of a square. But farther away from the hole the image will be round. This is the pinhole projection effect. When the image becomes round, you have an image of the sun. Since the sun is round, the image will be round.

1. Punch a square hole in an opaque material.
2. Let the sun shine directly on this hole on a clear day.
3. Project the image of the sun on a white card.
4. Examine the image of the hole in the shadow. If the card is held close to the hole, the shape of the image is the same as that of the hole—square. However, if the card is held farther away, it is round.
5. What is your explanation of this pinhole camera effect? (Note: It may be interesting to look up *camera obscura* in an encyclopedia.)



Title: Pinhole Reflection

Materials: A first surface mirror, a movie screen or a sheet of poster paper, and a clear day (Note: Although a first surface mirror is recommended for clarity, a regular mirror may be used. However, a regular mirror produces two images—one from the first surface reflection and one from the second surface reflection.)

Procedure: By reflecting the image of the sun on a screen, the surface features of the sun can be studied. This activity is similar to that of "Pinhole Projection," except that a mirror is used to reflect an image of the sun instead of allowing light to go through a pinhole. In order to get a pinhole camera effect, a mirror can perform the same function as a hole in an opaque material. However, this has the advantage of producing a much larger image due to the fact that light has been reflected for a much longer distance.

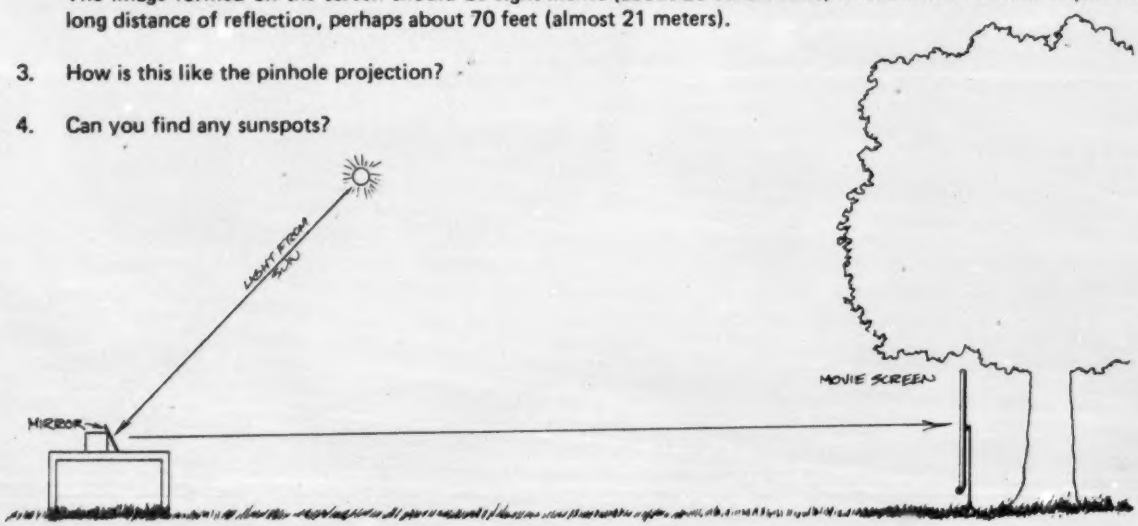
1. Mask a first surface mirror, leaving only a small square portion exposed (about one centimeter in diameter).

2. Place the mirror in a position so that it reflects the sunlight. By doing this, an image is formed on the movie screen, which has been placed in the shade. Secure the mirror with a ring stand and burette clamp, or some other innovative device.

   The image formed on the screen should be eight inches (about 20 centimeters) in diameter. This will require a long distance of reflection, perhaps about 70 feet (almost 21 meters).

3. How is this like the pinhole projection?

4. Can you find any sunspots?



Title: Refraction

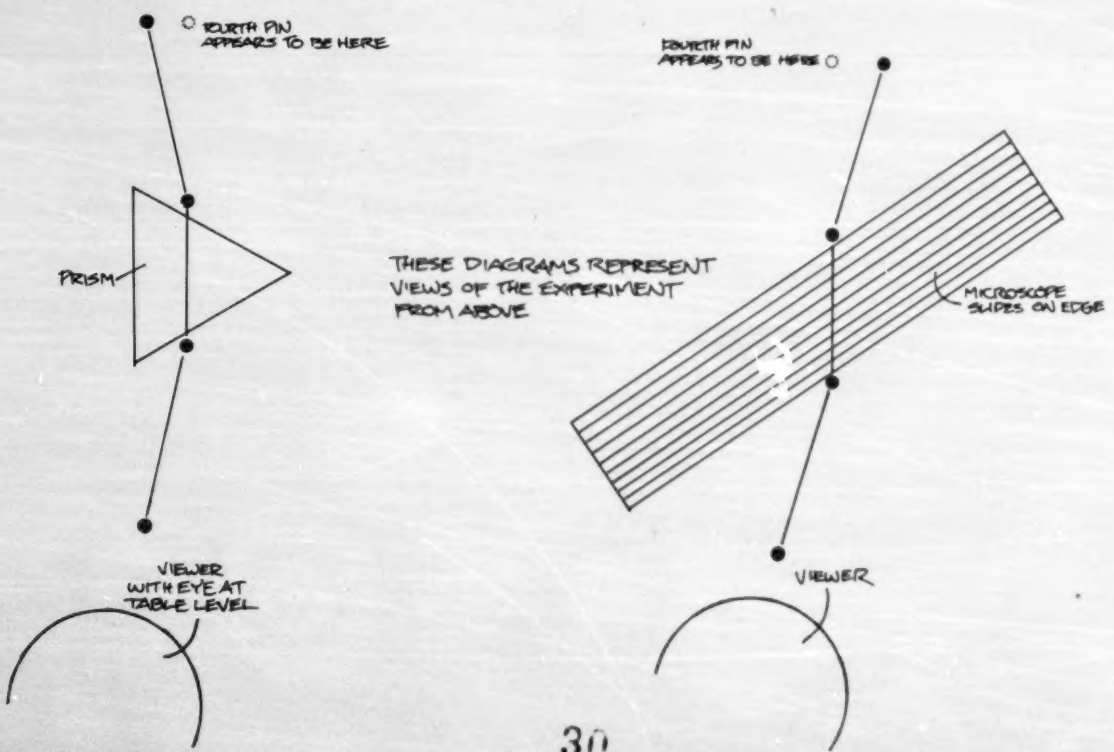
Materials: A prism, a piece of plate glass, 15 to 20 microscope slides, clear plastics, a glass of water, a piece of corrugated cardboard, and straight pins

Procedure: The bending of light as it passes from one substance to another is called refraction. In this activity the refraction of light will be observed through different materials.

1. Place a piece of corrugated cardboard on a table. Then place the prism on end over the corrugated cardboard.
2. Place one pin on each side of the prism.
3. With your eye at table level, look through the prism. Stick the third pin on one side of the prism so that it is in line with the other two pins. Next, place a fourth pin on the other side of the prism. Position the pins so that they appear to be in a straight line as seen **through** the prism—not above it.
4. When looking from above, are the pins lined up?
5. Why did the pins appear lined up when you looked at them from eye level?
6. Follow the same procedure while looking through the edge of a piece of plate glass or a stack of 15 to 20 microscope slides.
7. Do the same with a glass of water.
8. A piece of plastic.
9. A rock crystal.

All of the materials used in this activity refract a different amount of light. This is a property of the material and can be measured. This is called the *index of refraction.*

The speed of light is changed as it goes through one medium to another. Light travels fastest in a vacuum, slows down slightly as it travels through air, and slows down even more when it travels through a liquid or solid. The direction the light travels changes **because** the speed changes and only **where** the speed changes. This change of direction because of a change in speed is called *refraction.*


FOURTH PIN APPEARS TO BE HERE
PRISM
VIEWER WITH EYE AT TABLE LEVEL
THESE DIAGRAMS REPRESENT VIEWS OF THE EXPERIMENT FROM ABOVE
FOURTH PIN APPEARS TO BE HERE
MICROSCOPE SLIDES ON EDGE
VIEWER

Title: Lens: Imaging

Materials: A magnifying lens, a piece of white paper, and a clear day

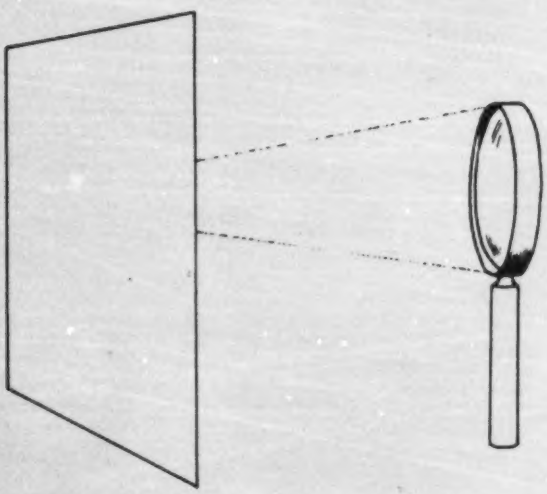
Procedure: Allowing light from a distant object to pass through a magnifying lens enables students to understand not only how a camera works, but also how the eye works.

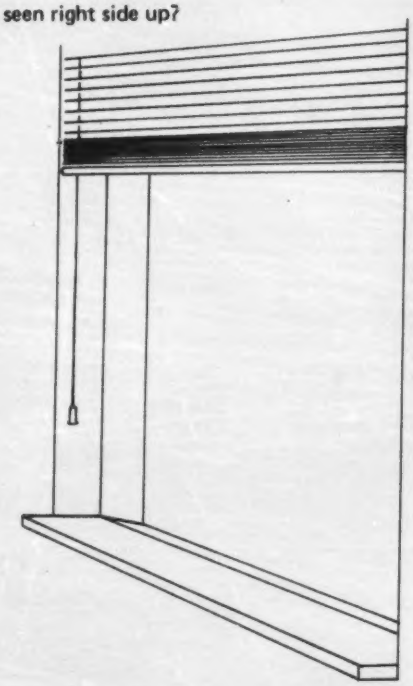
1. In a darkened room, stand ten feet or more from a window which is well lighted by the sunny outdoors.
2. Hold the lens so that the light from an object outside the window passes through the lens and strikes a piece of paper that is close to the lens.
3. Adjust the distance of the paper from the lens until a sharp image appears of the scene outside the window. Have a student move around outside the window while you watch his image on the paper. Movies?
4. Is the image erect or inverted?
5. Is the image larger or smaller than the object that has been focused on the paper?
6. Try blocking off parts of the lens with your fingers or a card.
   a. Does part of the image disappear? What does happen?
   b. From this part of the experiment, what do you think an observer sees when a clown waves his hand in front of a telescope?

The lens of the eye forms an image in this same way. The image from the magnifying lens is formed on a piece of paper, while the image in the eye is formed on the retina in the back of the eyeball.

A magnifying lens is found in the eye, as well as in the camera. The image is formed on the retina of the eye; while in the camera, the image is formed on film. A permanent record is made of the image on the film, whereas the image on the retina fades quickly. In the eye the retina contains nerve endings that carry messages of the image to the brain. The iris in the eye controls the amount of light, while in the camera it is the size of the aperture or the f-stop opening. The magnifying lens which is held close to the window produces an image that is inverted, smaller in size, and projected. The image formed on the retina of the eye and on the film in a camera has the same properties—it is inverted, smaller than the object, and projected. Although the camera and the eye have the same properties, the camera is not as good as the eye.

7. OPTICALLY, EYES ACT LIKE A CAMERA. So why is everything seen right side up?
8. Look up *camera obscura* in an encyclopedia.





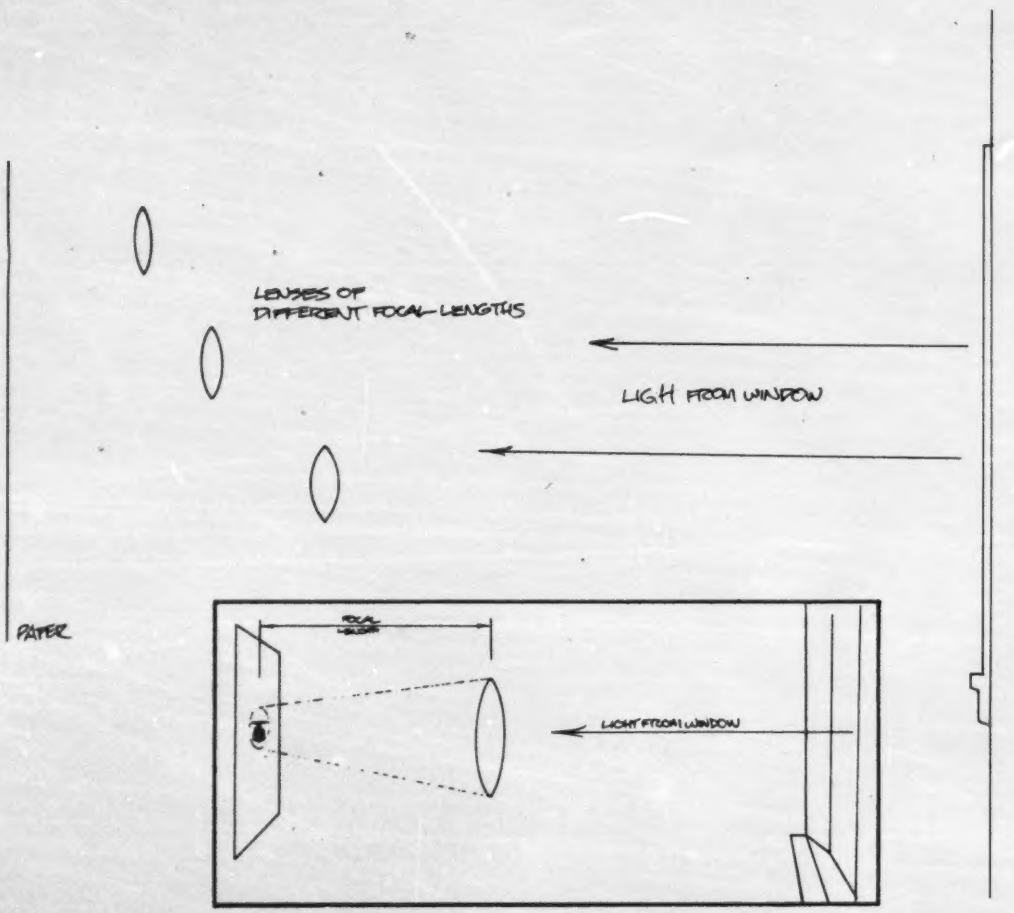
Title: Lens: Focal Length

Materials: Three magnifying lenses with different focal lengths, a piece of paper, and a clear day

Procedure: By allowing light from a distant object to pass through a magnifying lens, the focal length of the lens can be measured.

1. In a darkened room, stand ten feet or more from a window which is well lighted by the sunny outdoors.
2. Hold the lens so that the light from an object outside the window passes through the lens and strikes a piece of paper that is close to the lens.
3. Adjust the distance of the paper from the lens until a sharp image appears of the outdoor scene.
4. Is the image erect or inverted?
5. Is the image larger or smaller than the object that has been focused on the paper?
6. To find the focal length of the magnifying lens, measure the distance between the lens and the piece of paper, keeping the image in sharp focus.
7. Try the other magnifying lens. What is the focal length of each lens?
8. Does the size of the image depend on the focal length?

When light from a distant object passes through the lens, the distance between the lens and the image is within a silly millimeter of the focal length.



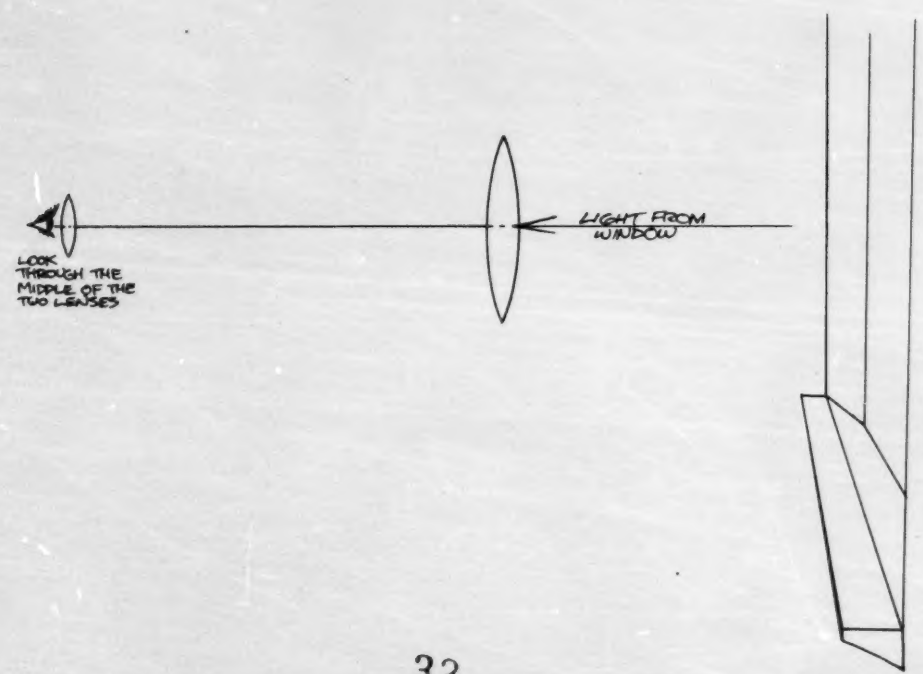
Title: Refracting Telescope: Make One

Materials: Two magnifying lenses with different focal lengths and paper (Note: One lens, the eyepiece, should have a focal length of 20-40 millimeters. The objective lens should have a focal length between 200-300 millimeters.)

Procedure: This activity involves making a refracting telescope by looking through two magnifying lenses with different focal lengths. The first telescope was invented in the seventeenth century by a Dutch optician, Hans Lippershey. When Galileo heard of Lippershey's invention, he built his first telescope (often called a Galilean Telescope). When Galileo pointed his telescope skyward, he made some outstanding discoveries. He discovered that the Milky Way was made up of millions of stars and that Venus had phases similar to those of the moon. He also discovered craters on the moon and the four moons orbiting Jupiter.

1. Stand inside a darkened room facing a window through which a bright scene is visible.
2. Hold one of the magnifying lenses so that the light from a distant object comes through the lens and focuses on a piece of paper. The paper should be close to the lens. The light from the window should pass through the lens and strike the paper on the opposite side of the lens from the window.
3. Adjust the distance of the paper from the lens until a sharp image of the object outside the window appears.
4. While keeping the image sharp, measure the distance from the magnifying lens to the paper. Within a millimeter, this is the focal length of that magnifying lens.
5. Find the focal length for the other magnifying lens in the same way. The lens with the shorter focal length will be the eyepiece. Hold this one close to your eye. The lens with the longer focal length is the objective and will be held farther away.
6. Look through the middle of these two lenses and adjust the objective lens until a sharp image of a distant object can be seen.
7. Is the object inverted or erect?
8. Is the image larger or smaller than the object?
9. Find out the difference between a Galilean, Newtonian, and Cassegrainian Telescope.

All that is needed to complete the refracting telescope is a tube around the lenses, adjusting knobs, and a stand to hold the apparatus.



Title: Reflecting Telescope: Make One

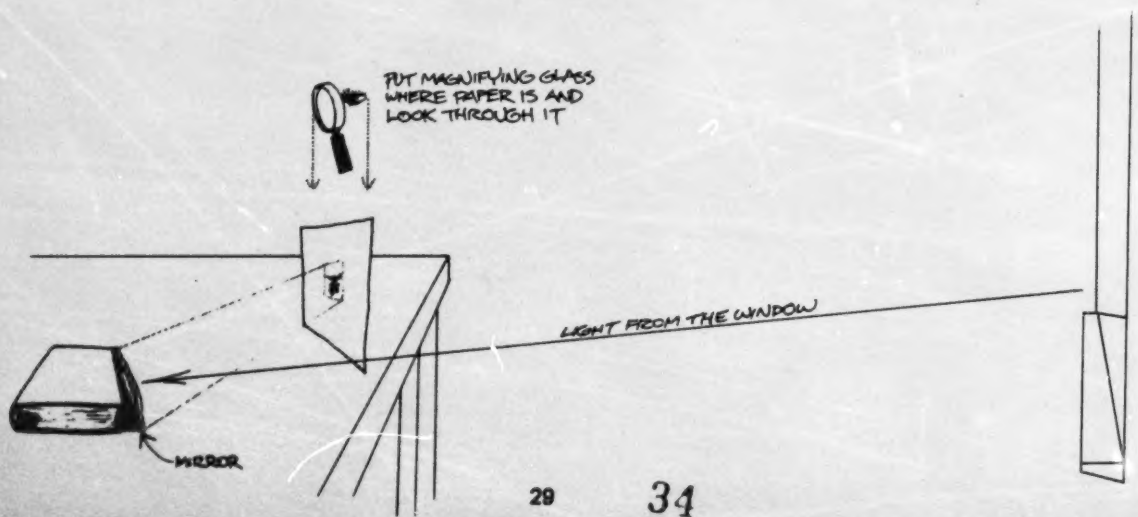
Materials: A cosmetic mirror and a magnifying lens with a short focal length

Procedure: When Sir Isaac Newton invented the reflecting telescope, he replaced the large objective lens in a refracting telescope with a mirror. The properties are the same for a magnifying lens (convex lens) and a cosmetic mirror (concave mirror). Both of the images are enlarged, inverted, and can be projected.

In this activity, light that is reflected off a cosmetic mirror will be viewed through a magnifying lens.

1. Mask a cosmetic mirror so that there is only a small opening (about one centimeter) in the center.
2. In a darkened room, place the mirror on a table ten feet or more from a well-lighted window. Place the mirror with the reflecting surface facing the window.
3. Focus the image of a distant object on a piece of paper that has been placed slightly out of line with the window. Adjust the distance of the paper from the mirror until there is a clear image on the paper. Make sure that the light from the window is not blocked.
4. Place the mask over the cosmetic mirror.
5. Remove the piece of paper. Put your head exactly where the paper was located. Now you are facing the cosmetic mirror with your back to the window. Move your head back and forth until the image is in focus.
6. With a magnifying lens, look at the opening in the mask.
7. Is the image enlarged or smaller?
8. Is the image inverted or erect? In astronomical telescopes, the image is inverted unless an extra inversion mirror is introduced, as in binoculars. When casually viewing an astronomical object, it really makes little difference if it is right side up or upside down.
9. Repeat the above experiment without the mask.
    a. What difference do you notice in the image? Look up *spherical aberration* in a physics book for an explanation. Astronomical mirrors are corrected for this.
    b. Does the size of the image depend on how much of the mirror is exposed?
    c. Try covering portions of the mirror with your hands. Does it block off part of the image? What does happen?

You have now made a reflecting telescope, often called a Newtonian Telescope in honor of Sir Isaac Newton. All that is needed now is a tube covering the apparatus, adjusting knobs, and a stand.



The solar system is defined as the sun, its nine orbiting planets, their own satellites, and a host of small interplanetary bodies such as asteroids and comets. Starting in the center of the solar system, the major bodies and their symbols are:

☉	Sun
☿	Mercury
♀	Venus
⊕	Earth
♂	Mars
♃	Jupiter
♄	Saturn
♅	Uranus
♆	Neptune
♇	Pluto

The symbols are sometimes used as convenient abbreviations today. A traditional memory aid for this outward sequence is Men Very Early Made Jars Stand Upright Nicely, Period. To avoid confusion about the positions of Saturn, Uranus, and Neptune, remember that the (S, U, N) is a member of the system too.